INDUSTRIAL DIAMOND REVIEW

Vol 18 No 214
SEPTEMBER 1958

Editor-in-Chief :
Eric M. Bruton

Managing Editor :
Patrick Greene

★

© 1958 *N.A.G. Press Ltd.—All rights reserved.*

PRINCIPAL CONTENTS

Generally Speaking	**Adamant**	**165**
Semi-automatic grinding of metallographic specimens of very hard materials	**Z. Ministr**	**166**
Diamond-Point Engraving on Glass		**170**
Blasthole Diamond Drilling at Flin-Flon (Conclusion)	**T. A. O'Hara**	**172**
How to Dress Diamond Wheels for Best Performance	**J. W. Ripple**	**174**

★

Industrial Diamond Review is published monthly at 1s 3d per copy, and is obtainable through newsagents and booksellers or by postal subscription (15s yearly, post free). Subscriptions in the United States of America are $2.50, and can be entered through the usual subscription agencies or direct through the publishers :—

N.A.G. Press Ltd
226 Latymer Court
London W.6.
(Telephone : RIVerside 2143).

★

Contributions of scientific, technical and practical interest, and news items, are invited, but responsibility cannot be accepted for the safety of MSS, drawings, photographs or other matter submitted. Material not accepted will be returned.

★

All editorial communications should be made to the Managing Editor at
2 Charterhouse Street
London E.C.1
(Telephone : FLEet Street 1577)

Generally Speaking

New Applications

There is, we feel sure, a vast field of new applications for diamond tools awaiting further exploration and exploitation, but, as so often happens in such matters, it is probable that as many new ideas will come from a chance observation as from deliberate investigation. One possible use occurred to us recently whilst watching a doctor opening an ampoule of anti-poliomyelitis vaccine before giving the injection. The neck of the ampoule was broken off with a pair of pliers, leaving a jagged edge and producing some nasty-looking small splinters of glass; furthermore, it appeared that there was a not inconsiderable risk of the ampoule's shattering, or at least cracking, so as to lose all or some of the vaccine. The idea of a small diamond file, preferably of the electro-deposited type, as a substitute for this rather crude method immediately suggested itself; and, in fact, something of this nature was designed some time ago. A modification of this idea soon followed, during a conversation with a lecturer in chemistry, who proposed the application to one edge of a normal small spatula of an electro-deposited diamond strip, say an eighth of an inch wide, or less, and about two inches long. This would make a very useful dual-purpose tool, particularly in the laboratory where chemical glass-ware is used. We are sure that any manufacturer who cares to take up this idea will find a ready market for such a product, and we hope that other people will be able to make further suggestions that can be taken up.

Educating the User

With most new applications, however, a further problem arises—that of educating the user, if he is a newcomer to diamond tools. Many prospective users are scared of diamond tooling—it sounds so expensive! In fact, as the experts know, it can always be shown quite clearly that, in suitable applications, diamonds are the cheapest way of doing the job, but the

SCIENCE MUSEUM LIBRARY

customer must be convinced. A month or so ago, we mentioned the use of diamond hones on normal steels, an application that until quite recently was thought to be unsuitable. New methods of manufacture have now made it possible to use diamonds in this way, and in one particular example where these hones have been substituted for the stones formerly used, the cost of the operation has been reduced by 50%, with an improved finish and a reduction in the time required—a convincing proof of economy.

It is most important when trying to convert users to diamond tools that they are clearly shown how to avoid wasteful use of the material, how to preserve and recover diamond from the waste resulting from abrasion processes, and how to make the best and most economical use of the diamond tools. Once converted, the results that can be achieved will do the rest.

ADAMANT

Semi-Automatic Grinding of Metallographic Specimens of Very Hard Materials

by Z. Ministr

(Translated by E. Sudek)

Summary

The author has used very hard materials, *ie* boron carbide and diamond, for polishing metallographic specimens. The grain size of the abrasive has been graded very evenly in order to complete the polishing as quickly and as economically as possible. Boron carbide was dispersed in paraffin on a cast iron disk, and the diamond was used as a paste on paper covering the disk of a single-wheel metallographic polishing machine. Twelve plastics mounts, containing in all 48 specimens, were fixed in a special holder and the polishing completed in about 50 minutes. The surface obtained was quite smooth and absolutely plane. Semi-automatic polishing as described in this article is suitable for the preparation of a considerable number of specimens simultaneously, provided that their hardness is approximately equal.

This paper presents some new findings relating to the semi-automatic grinding of hard metallographic specimens, and describes some modern equipment used for this purpose in Czechoslovakia and other countries. Amongst the general surveys dealing with this subject are the works of C. Z. Nesselstrasse[1], R. Pusch[2], and the catalogue issued by Buehler Ltd[3]. The author's own experience has been gained in grinding the hardest alloys, containing metallic carbides (mainly of tungsten), of the types used for the production of turning tools. Results were confirmed in the grinding of sintered permanent magnet material, which is of a comparable hardness.

Method of grinding

Mechanical grinding, either by wheels or belts, is rapidly replacing grinding with hand tools. The specimen can be either held in the hand, or several specimens may be mounted in a special mount that can be either rigid or movable during the grinding process. Grinding with movable mounts is called either automatic or semi-automatic, according to whether the movement is completely controlled by the machine or partly dependent on the operator.

Ordinary abrasive papers are of no use in grinding these very hard materials, since the material to be ground is harder than the abrasive. The grinding has to be carried out in the wet state, especially when the higher speeds and greater pressures are used, since the heat generated may otherwise change the original structure of the material. The risk of such change is especially great in hard, quenched materials. Some of the heat generated in grinding is conducted away harmlessly by the liquid, which also reduces the friction between the abrasive particles and the material being ground, and in this way also helps to prevent excessive heating of the ground surface, with the possible change in structure.

Table I. Melting points, microhardness, and atomic density of various abrasives

	Melting point: deg K	Microhardness load 50 g	Atomic density
Diamond ...	3,970	8000	0.293
Boron carbide ...	2,720	3700	0.227
Silicon carbide ...	2,450	3500	0.167
Titanium carbide	3,400	3200	0.167
Zirconium carbide	3,800	2600	0.134
Vanadium carbide	3,100	2800	0.166
Columbium carbide	3,730	2400	0.144
Tantalum carbide	4,150	1800	0.150
Chromium carbide	2,170	1300	0.177
Molybdenum carbide	2,960	1500	0.129
Tungsten carbide	3,140	2400	0.160

Characteristics of abrasives

The most important factor in grinding very hard materials is the hardness of the abrasive. It is evident that the greater the ratio between the hardness of the abrasive and that of the material to be ground, the more effective it will be. Because the hardness of any material is, to some extent, dependent on its melting point, we can define the abrasive power as the ratio between the melting point of the abrasive and that of the material to be ground. This definition is used because, on the one hand, the melting point of very hard materials can be more readily determined than their hardness, and, on the other, because the relation between melting point and abrasive power seems to be closer, as shown by Samuels[4], than the relation between hardness and abrasive power. The relation between abrasive power and atomic density appears to be even closer. Table I shows the melting points and microhardness of a number of materials, according to R. Kieffer and P. Schwarzkopf[5], and the atomic density, defined, according to H. Bottone, as the ratio of the product of the specific gravity and the atomic number to the molecular weight. It can be seen that the most efficient abrasives, diamond and boron carbide, have also the highest atomic density.

For grinding, an abrasive with a higher melting point (higher atomic density) than that of the material to be ground should be used. For economic reasons, it is sometimes necessary in the coarse grinding of very hard materials to use abrasives that are actually softer (having a lower melting point) than the workpiece. Such an abrasive is, of course, blunted quickly, and the consumption is very high.

Abrasives for very hard materials

For preparing specimens of very hard sintered cutting alloys, the hardest abrasives must be used, since these alloys contain from 70 to 95% tungsten carbide, with a melting point of about 3,140 deg K. Other carbides used for this purpose (TiC, TaC, etc) have melting points between 3,000 and 4,000 deg K. The binder commonly used for all these carbides is a cobalt phase having a melting point at over 1,570 deg K. The melting points of various carbides forming structural components of very hard materials are given in Table I. The ideal abrasive for such very hard materials is the hardest of all—diamond—with a very high melting point of 3,970 deg K and the highest atomic density of 0.293; boron carbide (atomic density = 0.227) and silicon carbide (atomic density = 0.167) are the next most suitable.

Alumina (alpha modification) is useless for grinding such materials because it has a relatively low melting point at 2,323 deg K. Silicon carbide, which is brittle, is used for rough grinding only, as it is the cheapest material. The relatively cheap and easily obtainable boron carbide is used extensively.

Diamond powder is sold by the carat (1 carat = 200 mg). Its abrasive power is so great that thousands of specimens can be ground with a few carats. According to Samuels[4] more than 10,000 specimens of medium hard materials can be ground with 5 ct of diamond powder, and our experience in the grinding of very hard materials indicates the consumption to be in the neighbourhood of 5 cts for 1,000 to 5,000 specimens with an average surface area of from 0.2 to 1.0 sq cm. Even after having ground this number of specimens, the diamond abrasive is not usually rejected because it has become blunt, but more often because of the destruction of the paper supporting the diamond containing paste, or because of contamination by a coarser abrasive. The diamond powder must be used correctly to achieve the greatest economy, and further savings can be effected by using boron carbide instead of diamond for coarser grinding, provided that precautions against contamination of the diamond are taken. There is no substitute for the finest grade of diamond powder used for polishing, because, amongst other reasons, the polishing power of diamond is connected with the particle shape.

Czechoslovakia imports boron carbide from the USSR, and the finest type imported is mesh number 320 (mean particle size 30 - 40 microns). A finer powder

Table II. Six grinding stages with various abrasives

Grinding abrasive stage	Manner of grinding	Peripheral speed: m/sec	grain size: microns	Time in minutes
1. Silicon carbide grinding wheel 60-80 K	Wet (in a stream of water)	15 to 20	200-300	—
2. Boron carbide on cast iron	Wet (paraffin suspension)	4.5 to 6	Up to 15	About 25
3. Diamond on cast iron	Dry	4.5 to 6	3 to 5	15
4. Diamond on wood	Dry or in oil	3 to 4.5	1.5 to 2	15
5. Diamond on paper	Dry or in oil	3 to 4.5	0.5 to 1	15
6. Alumina (modification gamma)	On cloth, wet (aqueous suspension)	3		30
			Total	100

SCIENCE MUSEUM LIBRARY 3 OCT 58

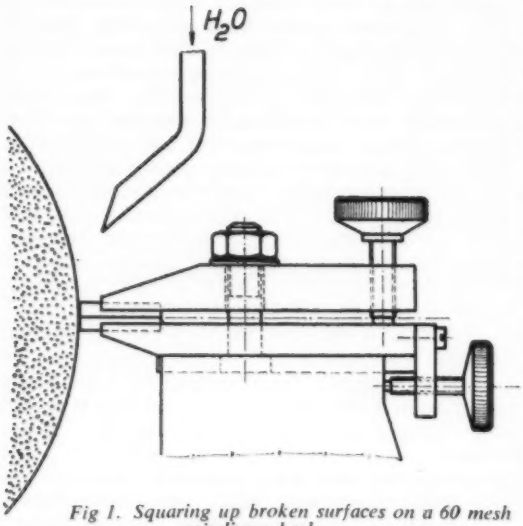


Fig 1. Squaring up broken surfaces on a 60 mesh grinding wheel.

can be otbtained by re-crushing and re-grading by a sedimentation or elutriation process.

Procedure for grinding very hard materials

In the metallographic laboratory of our Institute, we had to solve the problem of preparing a great number of specimens from very hard materials, in order to determine by statistical methods the effects of various influences on the production of sintered carbide tools. The method used previously for the preparation of a single specimen, as has been described in an earlier publication of J. Flasar[7], took approximately 1½ hours. This means that one technician can grind and polish only 5 specimens in a day. Six successive stages of grinding with various abrasives were used in this procedure, as shown in Table II. The sixth stage was polishing with alumina (gamma modification). The advantage of the procedure is that boron carbide is used for grinding and there is no need for the use of expensive diamond wheels with a metal or resin bond, as has been described by S. Blazek[8]. Older procedures, described in other literature[9-14], require a high consumption of the expensive diamond powder, and furthermore are in some cases very complicated[13].

Our aim was to make the grinding economical, and to mechanize it in such a way that each operator could complete the grinding of 100 specimens a day, *ie* 20 times as many as by the procedure given in Table II, and to reduce as far as possible the consumption of diamond.

Our specimens were in the form of small rods with a square section 5 × 5 mm, 30 or 50 mm in length, in which density, hardness, specific resistivity, and bending strength were first measured. After the completion of the last testpieces, 10 or 15 were knocked off with a hammer from the halves, and these small pieces had a number engraved on them for recording purposes.

The broken surfaces were then squared up in the machine shop on a rough grinding wheel (60 mesh), using a peripheral speed of about 70 ft/sec. The specimens were mechanically clamped in a holding device, which was pressed by hand against the wheel, as shown in Fig 1, so as to produce a flat surface, in order to reduce the time needed in the metallographic laboratory for the final grinding.

After this, 4 specimens were mounted in Dentacryl (a moulding plastic). To avoid any confusion the specimens were always put into the mould in the same manner with a slip of paper giving the serial numbers of the specimens attached to number 1. The other three specimens were numbered as shown in Fig. 2. Dentacryl has proved to be a very suitable material for the purpose, but at present it is very expensive.

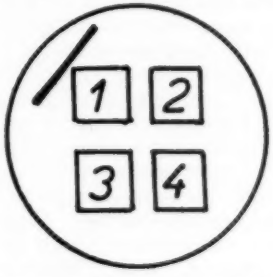
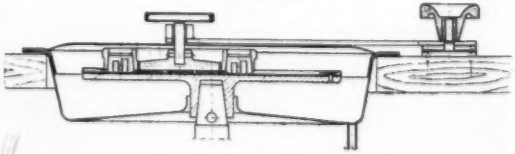


Fig 2. Numbering of mounted specimens.

The mould in which the specimens were mounted had the form of a cone with a slope of 1 : 10. A conical shape was advantageous for several reasons. It simplified the knocking out of the mounted specimens from the mould, and also their fixing in the holding device for semi-automatic grinding, as shown in Fig 3. Using a microscope, the mounted specimens were placed in a simple jig with a conical hole, so that the surface of the specimens was set normal to the optical axis of the microscope (Fig 4).

After the plastic had set, the mounts were

Fig 3. Specimens in holding device for semi-automatic grinding.



knocked out of the mould and pressed into the holding device for semi-automatic grinding. This device has 12 holes so that 48 specimens can be ground simultaneously. The separate stages of rough and fine grinding as given in Table III then followed. The regular reduction of particle size of the abrasives used is most important. The grading is shown on a logarithmic scale in Fig 5. It can be seen from this that there was a wide difference between the first and second stages of the original procedure (A) of Flasar, so that grinding with 15 micron boron carbide on cast-iron had to carried out for a long time. On the other hand, the difference between third, fourth, and fifth stages is so small that the fourth stage (grinding with 2 micron diamond on wood) can be omitted. In the new procedure (B) the graduation of the six grinding stages is almost even, so that each subsequent abrasive is always about one third the size of its predecessor; a wider grading had, of course, reduced the number of stages used, but each individual stage took longer. The curves in Fig 5 represent approximately the range of particle sizes in the abrasive.

Metallographic grinding machine

The separate stages of grinding are most satisfactorily carried out on single wheel grinding machines, where the risk of cross contamination is much less than in the older types of polishing machine with several wheels side by side. A modern type of single wheel grinding machine made by Buehler Ltd is shown in Fig 6. The wheels are readily interchangeable, and spare wheels can be kept in a compartment at one side of the table.

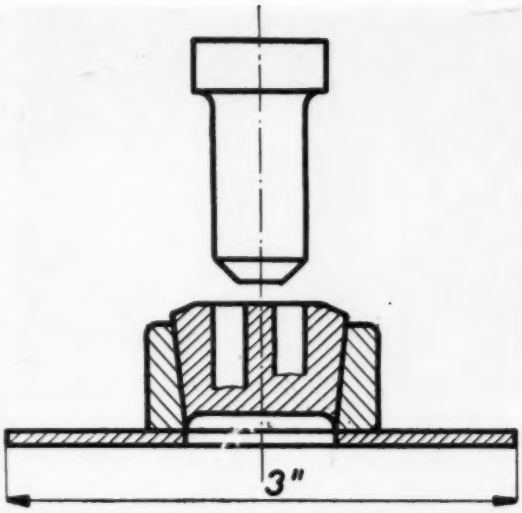


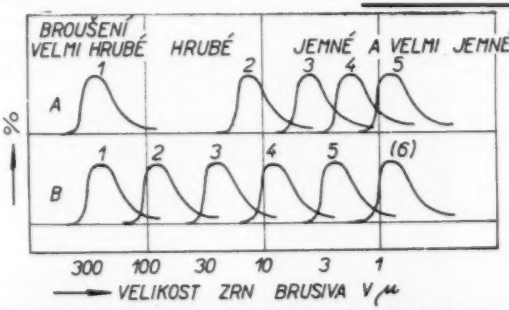
Fig 4. Setting specimens with the aid of a microscope.

This machine is powered by an electric motor with speed adjustable in the range 100 to 1,200 rev/minute. Once the wheel has attained the set speed, the rate of rotation will remain constant within 4± %, regardless of load, even at low speeds. On switching off, the wheel is brought to rest in a few seconds by a magnetic brake so that the control of grinding and the change of wheels can be carried out very quickly. The table weighs about 750 lbs, and each wheel is carefully balanced so that vibration is avoided, even at the highest speeds. It is convenient to carry out the second stage of grinding with 100 micron silicon carbide on a flat grinding disk glued to one of the interchangeable wheels of the grinding machine, as shown in Fig 7, provided that the machine can attain a high enough speed. In other cases it is necessary to fix the holding device on the magnetic table of a workshop

Table III. Grinding procedure

Stage	Grinding	Abrasive	Grain size of abrasive: microns	Grinding speed: m/sec	Grinding time in minutes
1.	Very coarse	SiC	300	20	—
2.	Coarse	SiC	100	15	10
3.	Coarse	B_4C	30	10	5 to 10
4.	Fine	B_4C	10	7.5	5 to 10
5.	Fine	Diamond	3	5	10 to 15
6.	Very fine	Diamond	1	2.5	10 to 15
				Total	40 to 60

Fig 5. The regular reduction of particle size is shown on this scale.



Translation: Brouseni = grinding; velmi hrubé = very coarse; hrubé = coarse; jemné a velmi jemné = fine — very fine; velikost zrn brusiva v = abrasive mesh size in microns.

Fig 6 (Left). Single wheel grinding machine made by Buehler Ltd.

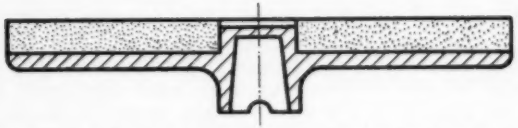


Fig 7. Grinding disk glued to an interchangeable wheel of a grinding machine.

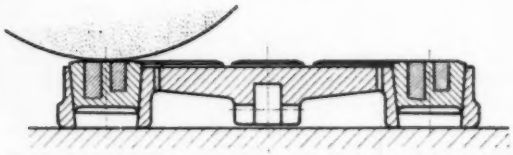


Fig 8. Holding device fixed on magnetic table of grinding machine.

grinding machine, as shown in Fig 8, and to grind the mounted specimens with a wheel at a peripheral speed of about 50 ft/second. The former procedure has the advantage of achieving an absolutely uniform flat surface for all 48 specimens, as has been shown when grinding softer materials at lower speeds. For the second stage of grinding very hard materials, a speed of about 50 ft/sec is necessary, which could not be reached on the equipment used for the work described in this article, so that recourse to the procedure shown in Fig 8 was necessary.

To be continued

Diamond-Point Engraving on Glass

Whether the Romans used diamond- or flint-points for engraving their glassware is a problem which has never been resolved. Both diamond and flint have found their proponents among the authorities, and it is safer, in briefly tracing the history of diamond-point engraving, to regard the 9th Century Islamic specimens in the Victoria and Albert Museum as the first definitely established examples of the use of diamond-points. European interest in the decoration of glass by diamond-point engraving appears to have been at its height from the late 16th Century to the early 18th Century, when wheel engraving superseded the diamond-point. Holland, Germany, and Italy all produced beautifully executed designs during this period. English interest reached its height during the late 17th Century and the first half of the 18th Century, and some of the finest English work was done at the time when the Continent was beginning to turn to the copper wheel. Responsibility for the eventual decline of the art in England has been attributed to John Ruskin's condemnation of Victorian engraving.

Revival

The revival of the diamond-point engraving of glass dates from the early 1930's, when Laurence Whistler, now a widely acknowledged engraver, started to produce startling and intricate designs through this medium. There are now some half-dozen diamond-point engravers in the British Isles, the majority of whom are members of the Crafts Centre of Great Britain, whose display and sales rooms are at Hay Hill, London W.1. Specimens and photographs of their work were recently on show at the Crafts Centre, where the Secretary, Mrs Sheila Pocock, MBE, MA, spoke encouragingly of an increasing public interest in engraved glassware. Sales figures of the Crafts Centre show that the sales of engraved glass now account for the third largest item in the Centre's sales revenue, being preceded by only pottery and musical instruments. A particularly notable and recent success for a Crafts Centre member was a commission received by Anthony Pope from the Corning Museum for a diamond-point engraving portraying the Roman invasion.

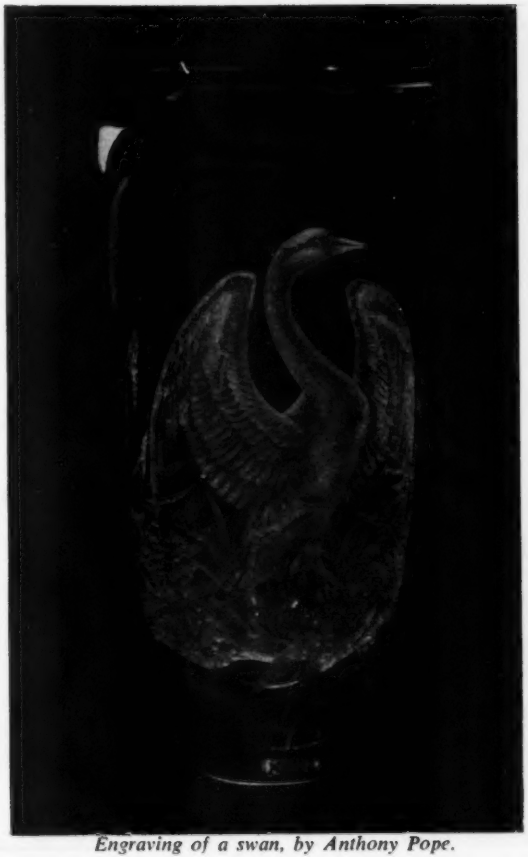
Crafts Centre display

Vases and sherry glasses appear to be the medium most favoured by the diamond-point engraver, and the majority of the pieces and photographs recently displayed at the Centre fell into these two categories. An attractive

exception was a photograph of a goblet, diamond-point engraved by David Peace, presented to the Archbishop of York by the Deans and Canons of Manchester. Further photographs showed glasses engraved by Stephen Richard, commissioned by the Minister of Works for British Embassies abroad, and the 19th Century goblet, also engraved by Stephen Richard, that was presented to Sir Winston Churchill, on the occasion of his 80th birthday, by Sir Anthony and Lady Eden.

When Sir Malcolm Sargent retired from his office as Conductor of the BBC Symphony Orchestra, members of the Orchestra presented him with a decanter and set of goblets on which the seven movements of Gustav Holt's Planet Suite were depicted in diamond engravings. The design and engraving were the work of Anthony Pope, and a photograph on display showed the decanter and the goblet Venus. Also of considerable interest, because of the quality of the work, was Laurence Whistler's engraving of Renishaw Hall on a goblet for Sir Osbert Sitwell, CH.

This goblet, the work of Laurence Whistler, was presented to the President of France by Her Majesty the Queen.



Engraving of a swan, by Anthony Pope.

On view

An extremely delicate example of stipple engraving with a diamond-point was provided by a wine glass, executed by Laurence Whistler, which bore the head of a girl. The stippling on this glass was so fine that it was necessary to view it in a certain light for the portrait to be discernible. Harry Warren Wilson showed a set of diamond-point engraved sherry glasses, and there were several examples of work by Mr. E. M. Dinkel, RWS, ARCA, who is head of the Design School at the Edinburgh College of Art. Mr. Dinkel recently sold an oil-painting to the Duke of Edinburgh.

A finely lettered crest, by Anthony Pope.

The tools and the glass

Ideally, special diamond-points are required for engraving, but it is possible to use the ordinary glass cutters' diamond available from ironmongers. Mr. Dinkel uses a special diamond-point manufactured by a well-known diamond tool manufacturer, and he reports excellent results from the tool. He has been using diamond-points for many years now, and on only one occasion has he had to have a diamond sharpened. The tool he uses resembles a slender ball-point pen, of which the shaft is made of wood, with a screw-on cap to protect the diamond from damage. Some diamond-point engravers design their own tools.

In Mr. Dinkel's opinion, English glass is unsurpassed as an engraving medium. Just as, in the early days of diamond-point engraving, English flint glass was widely favoured by engravers, in the present revival of the craft they rely to a great extent on English lead crystal. The Waterford glass, from Ireland, also shows great promise.

As the diamond-points and suitable glass are already available to the public, it is more than probable that the art of engraving would quickly become a popular hobby if manufacturers would trouble to stimulate public interest and provide a suitable 'kit' of, say, a diamond-point, a few small squares of glass, and a handbook of simple designs containing instructions for the beginner. As a suitable diamond-point retails at from 15 shillings to one pound, the cost of a kit need not be prohibitive.

Blasthole Diamond Drilling at Flin Flon

by T. A. O'Hara

Concluded from p 158

The explosive used in blasthole stoping is Forcite, a water resistant ammonia gelatin Class I dynamite. This explosive is used in 40 per cent strength and 1¼ in. diameter, although 1 1/8 in. powder may be used if the ground is shattered.

A powder factor of 0.22 lbs/ton is usual in open stopes drilled in the vertical ring pattern. The maximum hole burden is six feet. In pillar recovery, the presence of adjacent filled stopes may require lighter blasting with less burden per hole.

Rings are primed with milli-second delay caps not more than 40 of which are connected in series. Primacord is used as secondary priming to ensure complete detonation if any one or several detonators should fail.

Appreciable ore-body currents exist in Flin Flon Mine. These have been measured at values as high as 1.6 amps at 2 volts, which would explode electric blasting caps if good contacts were attained. Although our experience and testing work has indicated that the chance of accidental explosion in practice is remote, the existing hazard is minimized by grounding the track and pipe to the ore zones, and by supporting the cap lead wires outside the hole.

Winzes

An interesting application of diamond drilling is in sinking winzes for filling stopes or for recovery of horizontal pillars. The usual hole

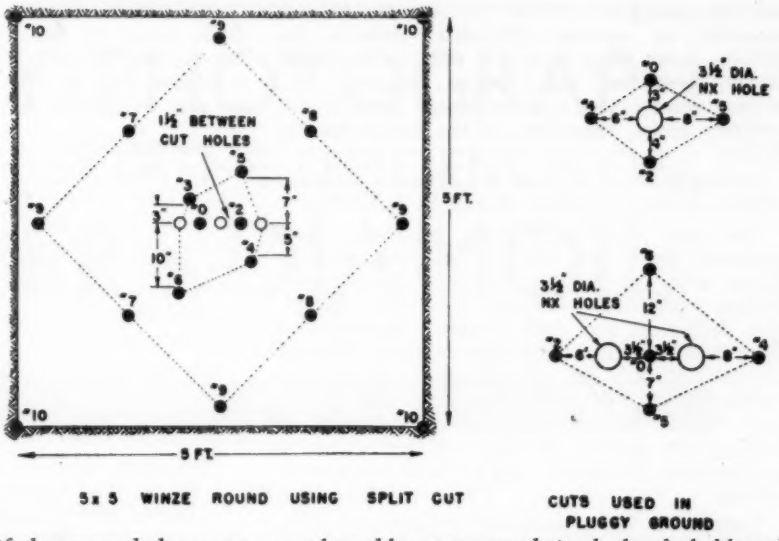


Fig 7. Diamond drill winze round.

pattern for 5 ft × 5 ft winzes is shown in Fig 7. EX core bits are used for drilling the cut and helper holes because they 'wander' less than pilot blast bits, and the core obtained from the cut and helper guides subsequent blasting operations. Pilot-blast bits may be used in drilling the holes in the square if the ground does not cause the bits to wander; otherwise, core bits are used for the square holes as well as for the cut and helper holes.

The location of the cut and helper holes at the breakthrough in the stope back is tested by lowering a 1¼ in. diameter electric lamp through one of the cut holes, usually the No O hole to be loaded later. The distance between the No O hole and the other unloaded cut holes and the helper holes is derived by measuring the distance the lamp must be lowered beneath the stope back before reflected light can be seen in the adjacent holes. If any one of the cut or helper holes is heavy, *ie* too far from the No O loaded cut hole, an additional hole may be drilled to replace it in the blasting sequence. If several holes are 'heavy,' another cut hole may be selected as the No O hole if it is better located to lighten the burden on adjacent holes.

Great care is taken to ensure that holes are drilled parallel to each other. 'Wandering' of holes is usually less than 2 in. over 50 ft of winze, and, because holes usually wander in the same direction, the blasting sequence is not usually affected. Winzes up to 88 ft long have been drilled successfully by the diamond drill, although the usual length of winze is less than 50 ft.

The length of lift taken is guided by the core obtained during drilling and only one type of ground is blasted in each lift. In homogeneous ground, the cut is carried 2 ft ahead of the square in lifts of 6 to 9 ft, the longer lifts being taken in easy breaking ground. Plugged holes are cleared by compressed air, the last hole blasted being cleared first.

In difficult breaking ground, one or two NX holes may be used for the cut as shown in Fig 7. The cut used for 7 × 7 ft winzes is the same as that used for 5 × 5 ft winzes, but an additional five holes are required in the square.

Data obtained from driving 26 diamond drill winzes to an average depth of 40 ft are: ft drilled/shift = 81.0; manshifts/ft of winze: drilling = 0.62, loading = 0.32; labour cost/ft = $21.00; explosives cost/ft = $3.68; bits and supplies cost/ft = $2.48. Total direct cost/ft of winze = $27.16. Although this cost is about twice the cost of raises, it is much less than the cost of driving winzes by conventional methods which are rarely employed at Flin Flon.

Diamond drilling costs

Most blasthole diamond drilling is contracted at 28 cents/ft drilled, and drillers receive a bonus equal to their contract earnings less wages

Table IV

Diamond drilling 1953-54

Footage drilled	844,447	feet
Tons blasted	1,805,431	tons
Machine shifts (2 men/machine)	6,413	shifts
Feet drilled/machine shift	131	feet
Tons blasted/foot drilled	2.14	tons
Cost/foot drilled:		
Labour cost (wages)	20.7 c	/ft.
Labour cost (bonus)	11.5 c	/ft.
Bit cost	7.6 c	/ft.
Drill and rigging repairs	6.1 c	/ft.
Rods, shells, and drilling supplies	2.2 c	/ft.
Total direct cost of diamond drilling	**48.1 c**	**/ft.**

and bit charges. When drilling accuracy is essential, or unusual difficulties prevent the drilling crews from earning a reasonable bonus, drilling is placed on 'special contract,' and drillers receive the average bonus paid to the contract crews, regardless of the actual footage drilled.

Performance and cost/ft of all diamond drilling during 1953-54 is shown in Table IV.

The cost of drilling long blastholes with diamond drills (48 cents/ft) is only slightly higher than the cost of shorthole development drilling with rock drills (41 cents/ft for labour, bits, drill steel, and drill repairs). Inasmuch as the drilling speed of rock drills is about one and one-half times that of diamond drills, and carbide-tipped drill steel is made locally at low cost ($6.25 per shank), this comparison of drilling cost reflects the high drilling efficiency per shift and the low bit cost attained in diamond drilling.

Tests show that blastholes drilled with rock drills and sectional steel are more costly than those drilled by diamond drills, except when holes are inclined upward and are less than 30 ft long.

It is concluded that rock drills and sectional steel are not likely to replace diamond drilling for blasthole work at Flin Flon. Diamond drills have, in fact, replaced rock drills for development work such as winze sinking, raise enlarging, station slashing, and drilling holes for pipe or electric cable.

Acknowledgements

The writer wishes to thank members of the Flin Flon mining staff, in particular Mr A. Johnson, Diamond Drill Foreman, for their advice and assistance during the preparation of this paper. The permission of the management of the Hudson Bay Mining and Smelting Company Limited to publish data in this paper is gratefully acknowledged.

For readers of *Industrial Diamond Review* who are interested in the history of diamond blasthole drilling at Flin Flon, the following publications give further information on the subject:

'Blasthole diamond drilling at East Malartic,' by C. C. Kamm, *Engineering & Mining Journal* 1940 (Nov);

'Blasthole diamond drilling of Flin Flon,' by G. M. Proudfoot, *Canad Inst Min & Metall Trans* 1943 Vol 46 pp 277-290;

'Blasthole diamond drilling,' by O. V. Lindquist, published in 1944 by J. K. Smit & Sons Inc., New York, N.Y.

*How to Dress Diamond Wheels for Best Performance**

by J. W. Ripple**

This article reviews the dressing and cleaning methods in an attempt to assist shops using diamond wheels to get the most out of them. In grinding with abrasive wheels there is a very close relationship between correct dressing and cleaning of the wheel face on the one hand, and cutting effectiveness and wheel life on the other. This relationship becomes even more apparent, in the case of diamond wheels, because of the high wheel costs involved. Because of the significant difference in the characteristics of each, distinctions are drawn according to the type of bond, ie vitrified, resin, or metal.

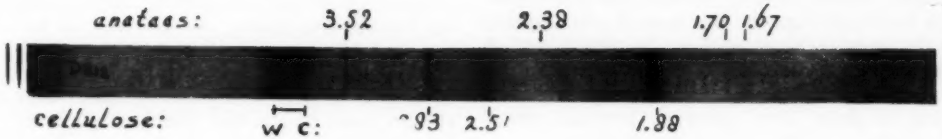
Dressing the diamond wheel

Dressing diamond wheels involves one or both of the following: removal of surface grits that have become dull through use, undercutting the bond to expose new sharp points, and cleaning the sludge from the wheel face that has accumulated in the grinding operation. Since it involves a smaller amount of bond removal, the cleaning operation is usually less severe on the wheel.

Excessive dressing—either through the use of the wrong abrasive or faulty procedure—materially shortens wheel life. In order to conserve diamonds the wheel face must be kept sharp so that the cutting action can be most effective. However, the dressing should not be so severe as to lose good diamonds.

There are three different methods for dressing straight (DIT) type diamond wheels. In the first, the wheel remains on the grinding machine spindle and runs at its regular operating speed. The dressing is effected by an abrasive wheel mounted on a toolpost grinder. The axis of this grinder is set at 30° to the axis of the diamond wheel. Light downfeeds are employed, and the dressing wheel is traversed along the axis of the diamond wheel until the proper face condition is attained. Grinding should be wet if possible. The 30° angle between the two wheels causes a scrubbing or scuffing action which materially assists the operation. For metal-bonded or vitrified-bonded diamond wheels, a silicon carbide vitrified dressing wheel, 100 mesh, M grade, running at a maximum speed of 6,000 surface ft/min is recommended. The removal of stock

X-RAY PHOTOGRAPH
PROVES EXTREME EFFICIENCY OF
SUPER - DIAMOIL



A case story :

A diamond wheel which had been cleaned with a conventional coolant during some weeks, was superficially cleaned with a piece of cotton soaked in SUPER-DIAMOIL.

The cotton was covered with black patches immediately.

This X-Ray Diffraction photograph (Guinier Camera) shows that these black patches were caused by tungsten carbide particles and diamond dust still sticking in the diamond wheel.

One perceives the broad lines of WC (the others show, cellulose and pigments of the textile).

These particles *sticking* in the diamond wheel clog the wheel. So the wheel does not grind sufficiently and the operator will automatically increase grinding pressure.

Higher grinding pressure means higher grinding temperature.

Consequently heavy wear of the diamond wheel and a great risk of cracks in the hardmetal workpiece.

Cool, Clean and Lubricate your precious diamond wheels exclusively with

SUPER - DIAMOIL

and save up to 50% on your diamond wheel cost.

Surface finish from 2-5 Nano
(1 Nano = 1/1.000.000th of a mm)

We are open for a few more agencies abroad.

DANINGER HANDELMAATSCHAPPIJ N.V.
Laan van Meerdervoort 91
THE HAGUE (The Netherlands)

from the diamond face should be very slow—about 0.0005 to 0.001 in./minute. For resin-bonded diamond wheels, an aluminium oxide vitrified dressing wheel, 100 mesh, M grade, should be employed. The surface speed remains the same.

The second method consists of supporting the diamond wheel between flanges on the work-centres of a cylindrical, power-driven grinding machine. An abrasive dressing wheel is mounted on the spindle of the machine. With the diamond wheel rotating at approximately 200 surface ft/min the table is traversed back and forth. Hand turning of the diamond wheel should be avoided, since the uneven motion will cause flat areas to be ground on the periphery. A silicon carbide vitrified wheel, 100 mesh, K grade, is recommended for this purpose. The dressing is done wet using a dressing wheel speed of about 6,000 surface ft/minute.

The third method employs a brake-controlled dressing device. This consists of a dressing wheel in a small fixture mounted on the machine table below the diamond wheel; it is presented at a 30° angle, and the diamond wheel drives the dressing wheel by contact. The dressing wheel is retarded by a brake on the wheel spindle, and the scrubbing action which results sharpens the face of the diamond wheel. Here again, recommendations are to use a silicon carbide vitrified dressing wheel, 100 mesh, M grade, for metal-bonded or vitrified-bonded diamond wheels ; and an aluminium oxide vitrified dressing wheel, 100 mesh, M grade, for resin-bonded diamond wheels.

The cutting faces of cup, dish, and other side-grinding types of diamond wheels—with resin, metal, or vitrified bonds—can be trued by machine grinding using the same abrasive wheel recommendations as previously described, or by hand lapping with a loose abrasive—a flat cast iron or glass plate can be used for such operations. A small quantity of 220 mesh silicon carbide powder is recommended for lapping wheels and the medium range of mesh sizes. Coarser or finer mesh sizes may be used for coarser and finer mesh wheels. For example, 60-100 mesh silicon carbide abrasive powder may be used for diamond wheels 80-180 mesh. For diamond wheels of 320 mesh and finer, 220 mesh aluminium oxide is recommended, since silicon carbide may charge the wheel face and later produce scratches in the work. The lapping operation can be done dry by hand. A figure 8 motion is used, and the wheel is given a turn after each figure in order to maintain parallelism of face and back.

Cleaning the diamond wheel

Load and glaze are usually cleaned from diamond wheels with the dressing stick which is provided with each wheel. Metal-bonded or vitrified-bonded wheels may be cleaned with a silicon-carbide vitrified dressing stick, 80 mesh, M grade; resinoid-bonded wheels with a 120 mesh, H grade, vitrified stick. The stick is applied manually to the face of the wheel while running at operating speed. Normally, the operation takes from 3 to 10 seconds to restore cutting efficiency, depending upon the bond and the amount of load and glaze removed.

Thin metal-bonded wheels, such as those used on cut-off operations, can be dressed by a short cut through a material like sandstone, limestone, conder block, or groggy type refractory brick. This type of wheel may also be sharpened with a silicon carbide vitrified dressing stick, 80 mesh, M grade. The stick is plunged directly into the periphery of the wheel.

Resin-bonded cut-off wheels can, in many instances, be satisfactorily cleaned with an aluminium oxide vitrified dressing stick, 120 mesh, H grade. If the load or glaze is light, plunging block or stick pumice into the wheel will do an effective job.

Conclusions

Excessive loading or glazing of a diamond wheel indicates improper operating conditions or the use of the wrong wheel. Too frequent dressings may indicate the need for another wheel type or grade. Burning of the wheel face is caused by improper usage or lack of coolant. Assistance in establishing the proper conditions and the wheel for the job can be obtained by calling for professional engineering help which is provided by wheel manufacturers' abrasive engineering services. Experts in all phases of abrasive wheel applications are available for the asking.

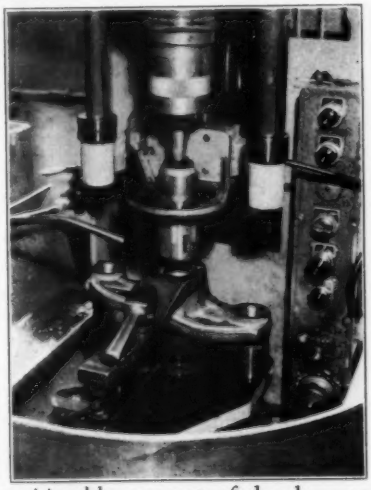
* *Grinding and Finishing* 1958 Vol 3 (10) pp 32-34 (Feb)

** Abrasive Engineer, Carborundum Co

Diamond Hones Used on Soft State Forging

Considerable savings have been achieved by the use of Diagrit hones for honing the rocker arm for the Rootes three-cylinder direct-injection water-cooled diesel engine. Two model 721 Hydrohoners are placed side by side, the first machine is fitted with type DH 13 $1\frac{1}{4} \times 5/16$ for honing the two outer bores, and the second machine uses type DH 16 $1\frac{3}{4} \times 5/16$ for honing the larger centre bore. (Fig. on next page.)

Rocker arm larger bore	**2.750 in. diameter**
Material	EN 16 T 50 ton forging
Stock removal	0.003—0.004 in.
Finish required	36-40 micro-inches
Large centre bore	2.750+0.0005 in. —0.000 in.
Lubricant	Paraffin
Diamond hone size	1¼ × 5/16 in.
Bond of diamond hone	Bronze
Life obtained from grit hones	approx 70 bores
Life obtained from Diagrit diamond hones	5,500 bores
Small outer bores	**1.5 in. diameter**
Material	EN 16 T ton forging
Stock removal	0.003—0.004 in.
Finish required	36-40 microinches
Smaller outer bores	1.500+0.0005 in. —0.000 in.
Lubricant	Paraffin
Diamond hone size	1¼ × 5/16 in.
Bond of diamond hones	Bronze
Life obtained from grit hones	Approx 100
Life obtained from Diagrit diamond hones	7,500.



A considerable amount of development work was necessary to hone the 50 ton EN 16T forging in the soft state, and various bonds were tried before a satisfactory combination was found that would give the production rate, the life, and at the same time prevent glazing of the hone.

Grit stones used on the smaller bore had an approximate life of 100 bores, and to warrant the extra cost, diamond hones had to complete 3,440 bores. In fact, the diamond hones have a regular life of 7,500 bores per set, thus showing a considerable saving over the conventional grit stones. The grit stones used on the larger bore gave roughly the same performance, and in that case it was necessary for the diamond hones to complete 2,184 bores to be economical. Diagrit hones produce 5,500 per bore.

The stock removal from both bores was 0.003—0.004 in., and a finish of 35 microinches was required; the diamond hones give a consistent finish of 32-36 microinches.

The Edge-Master— Australian Pencil Edging Machine

Details of a new pencil edging machine for use by the glass industry have recently been released by the manufacturers, Diamond and Boart Products (Australia) Pty Limited.

General

From previous experience with this type of machine, it was known that vibration and out-of-round running of the wheel drum adaptor could cause more diamond wheel wear than the actual glass grinding operation. Scalloped edges produced on the glass by an eccentric diamond wheel necessitate a wheel truing operation with a consequent loss of wheel diameter. In order to eliminate eccentric running and the wasteful truing process, the Edge-Master has been constructed to very fine tolerances. It is supplied without a truing device, and, although the manufacturers will supply one on request,

Telegrams:
Inland: Eldevries, Cent, London.
Overseas: Eldevries, London.

L. de VRIES & SON LTD.

Telephone:
HOLborn 5097

11, HATTON GARDEN, LONDON, E.C.1.
ESTABLISHED 1890

WE STOCK DIAMONDS FOR ALL INDUSTRIAL PURPOSES

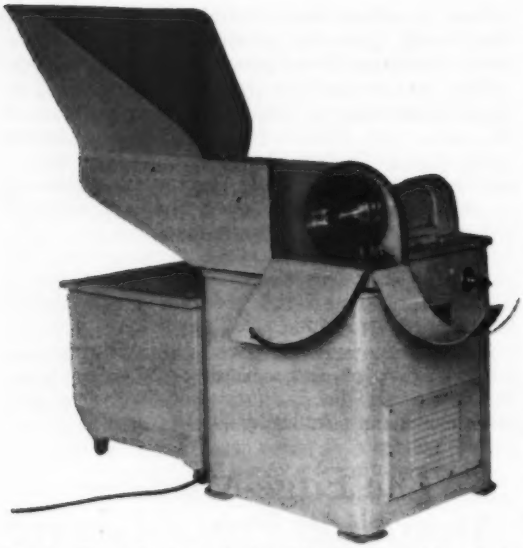


Fig 1. General view of the Edge-Master with splash guards removed.

they point out that one, and possibly two, new pencil edging wheels can be supplied for the cost of the truing device. Users are recommended to return worn wheels to the manufacturers for truing.

Components:

The principal components of the Edge-Master are briefly described in the following table:

Component	*Specifications*
Housing	High stability nickel iron of fine grain structure; mounted on hand-scraped pads on 1 in. thick base plate, also hand-scraped.
Spindle	Stress relieved, heat treated nickel chrome steel; 2½ in. diameter, precision ground; dynamically balanced.
Bearings	Radial thrust 4in. diameter; pre-loaded to 120 lb pressure; labyrinthe sealed.
Lubrication	Pre-lubricated; following 8 hr day use for full working year, the manufacturers recommend examination by their technicians.
Wheel mounting drum or adaptor	Available in either durax or stainless steel; stress relieved and precision machined; dynamically balanced.
Base	¾ in. steel plate; top plate of ¾ in. plus a further 1 in. thick plate; hand-scraped to accommodate housing; vented for air circulation; anti-vibration mounted.
Water supply	Chrome plated taps provide for (*i*) direct connexion to water main (for use without suds tank); (*ii*) direct connexion to suds pump for use with recirculated soluble oil; and (*iii*) a water-main outlet which permits the filling of the suds pump without removing it from the machine. Water supply to each wheel can be controlled individually.
Splash guards	The 14 gauge steel guards are hinged to provide access to the diamond wheels and water supply. The splash guard extension can be removed to facilitate grinding of long sheets, and a rubber covered roller is provided as a support for the long sheets.
Electrics	A totally enclosed 1 hp 2,800 rev/min motor; protected against vibration and overload; AC, 415 volt, 3 phase, 50 cycle.
Suds tank	50 gal capacity; two compartments.
Coolant pump	10 gal/min capacity; AC, 415 volt, 3 phase, 50 cycle.
Drive	Endless nylon belt.

Lapidary attachment

The attachment shown below is suitable for use on any polishing machine, and it is designed for producing diamonds for tools with radii of 0.1—6.00 mm. The attachment's pivot type mounting, clearly shown in the illustration, permits the whole width of the scaife to be used. Radii are determined by a cone, pivoted on a ball-bearing, which is moved through a connecting rod and blade. This arrangement is designed so as to eliminate dead spots. A cross-groove permits the centring of tools, and the toolholder can be moved by an endless screw. The movements are performed by one or two small motors.

The attachment is produced by Bunter SA, Lucens, Switzerland.

Next month's issue of Industrial Diamond Review will contain a report on the 1st Italian Machine Tool Exhibition held in Milan from September 11 - 21.